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PHOTODEFINED DIELECTRICS

## (57) Abstract

A method for metallizing microvias and high density interconnects in photodefined dielectrics using novel low temperature, fast curing metal-organic compounds. The materials are applied to the developed photoimage by any convenient printing process and thermally cured to well-consolidated pure metal conductors at the same time and under the same conditions that the dielectrics are cured and cross-linked to infusible, insoluble resins.

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## **Method and Compositions For Metallizing Microvias and High Density Interconnects in Photodefined Dielectrics**

### **Background of the Invention**

Manufacturing electronic devices such as printed circuit boards and semiconductor devices requires the placement of high density, patterned layers of conductive material on a substrate. The method of placement must be suitable for high production rates and it must produce precise patterns. These requirements have become increasingly important with the recent development of surface mounting technology used to mount components on a substrate.

One method is to etch the patterns on copper-clad laminates using well known negative photo-resist procedures. This process is complex, slow, expensive, and produces hazardous solvents and other waste materials.

Another method is the process of applying a pattern of conductive ink or paste directly onto the surface of a non-conductive substrate and then curing it. The curing operation of some conductive inks and pastes requires curing at elevated temperature above 450 °C before they become conductive. As a result, their use is limited to substrates which can withstand extreme temperatures such as those made from ceramics. Another type of ink includes epoxy resin, which is unsuitable for high performance circuits because of their poor electrical conductivity. They are also unsuitable for high speed, mass production because of long cure times. Yet another known method uses a radiation curable ink containing particles of electrically conductive metal and organic resins curable with radiation. This ink cures rapidly, resulting in higher production rates. However, the metal particles in it must have a certain predetermined shape for the ink to cure satisfactorily, and because the metal particles are not welded together, their electrical conductivity is still poor.

Finally, in placing multiple layers of patterned conductive material using current methods such as those described above, production rates decrease

substantially. This decrease occurs partly because of the added step of electrically interconnecting the conductive arrays comprising the various conductive layers. A conventional method of interconnecting the conductive layers of multi-layer printed circuit boards and of adding conductors to the surface of semiconductor devices consists of forming a via through the conductive layers, catalyzing the walls of the via, electroless plating the interior of the hole, masking the surface copper foil with a resist, exposing and developing the resist, and electroplating the walls of the hole with an electrically conductive material. The plating connects the exposed edges of the conductive layers and creates the circuit connections between them. Finally the resist is stripped and the unwanted copper foil is etched away. This operation can take considerable time.

#### **Brief Summary of The Invention**

To achieve the ultimate in high resolution circuit traces and overcome the shortcomings of the current methods, the presently disclosed technology uses photo sensitive dielectric materials in combination with low temperature curable, metal forming compositions to produce the high density circuit patterns and filled vias in multi layered devices. A photosensitive dielectric is applied to the surface of the circuit and exposed to the desired pattern of microvias, interconnect traces and conductor traces, which can be very fine. The negative image is developed in the usual way by washing the unpolymerized, unexposed material away. The composition of the present disclosure is applied by printing or doctor blading it into the microvias and interconnect traces. The circuit is heat treated in an oven which consolidates the composition into pure metal conductors and completely polymerizes the photo imageable dielectric into an infusible, insoluble resin. An additional layer of solder mask or potting compound can be applied to protect the finished circuit in the usual way or one or more additional layers of dielectric with microvias and traces can be placed on the previous existing layer.

The use of PARMOD™ compositions, commercially available from Parelec, LLC, which are disclosed in Applicants' copending PCT Application PCT/US97/16226 filed 12 September 1997, the application in total being hereby incorporated by reference, to fill the microvias and form interconnects overcomes many of the problems associated with currently used methods for forming patterned conductors and microvias in the production of intricate, multilayered circuits on a substrate.

PARMOD™ mixtures contain a Reactive Organic Medium and metal flakes and/or metal powders. The ROM consists of either a Metallo-Organic Decomposition (MOD) compound or an organic reagent which can form such a compound upon heating in the presence of the metal constituents. The ingredients can be blended together with rheology modifying organic vehicles well known in the art, if necessary, to produce printing inks or pastes. These inks can be printed on a temperature sensitive substrate and cured to well-consolidated, well-bonded electrical conductors at a temperature low enough so that the substrate is not damaged. The curing process occurs in seconds at temperatures far below those used for conventional sintering of thick film inks and pastes.

The fast, low temperature curing capability of PARMOD™ compositions, as well as their ready application by printing, makes it possible to use them to metallize high density interconnects and microvias using a very simple and low-cost process. The process is particularly applicable to processes using photoimageable dielectrics in which the dielectric material remains as part of the finished product, rather than being stripped and discarded, as with conventional resists. Examples of such photoimageable products are Pyralin® from DuPont, Probelec® from Ciba Geigy and Probimide® from Olin Microelectronic Materials.

The process comprises forming a layer of a dielectric on an existing printed circuit or semiconductor device. Microvias are formed in the dielectric in alignment with circuit traces and pads of the underlying printed circuit or semiconductor device. Interconnect traces can also be formed in either by printing PARMOD™ traces directly on the surface of the photodielectric or by filling photo-defined trenches in a

subsequently applied layer of the dielectric between the microvias underlying circuit traces and pads for mounting circuit components by soldering.

PARMOD™ is then applied to fill the microvias and interconnect traces. The PARMOD™ can be applied by any suitable method, including screening, printing, stenciling, and doctor blading or using a squeegee. The PARMOD™ is cured with heat, forming a solid metal conductor in the microvias and interconnect traces.

A next layer of dielectric can be formed over the existing dielectric layer. Microvias and interconnect traces are formed in this next dielectric layer in alignment with microvias and interconnect traces in the underlying dielectric layer. The microvias and interconnect traces are filled with PARMOD™ and the PARMOD™ is cured.

The steps of forming a next dielectric layer with microvias and interconnect traces; filling the microvias and interconnect traces with PARMOD™; and curing the PARMOD™, can be repeated indefinitely as necessary to produce complex, multi-layered circuit boards or semiconductor devices.

#### **Brief Description of the Drawings**

Preferred embodiments according to the present invention will be described in detail with reference to the following figures, wherein:

Figure 1 is an illustration of an electronic device produced by the method of this invention having metallized microvias and printed circuit traces.

Figure 2 is an illustration of an electronic device produced by the method of this invention having metallized microvias and interconnects.

Figure 3 is an illustration of a multi-layered device produced by the method of this invention.

### Detailed Description of the Invention

Preferred compositions useful for filling the vias and forming the traces are comprised of a metal mixture and a Reactive Organic Medium (ROM). These compositions can be applied to thermally stable substrates and cured to well-consolidated, pure metal vias, interconnects and circuit traces by heat treatment. The compositions exhibit a critical temperature above which they undergo a transformation to well-consolidated electrical conductors with a resistivity only two to four times the bulk resistivity of the metal in question. The electrical conductivity is equal to that obtained by conventional high temperature metal powder sintering in conventional thick film compositions on ceramic substrates. Remarkably, this consolidation process takes place at temperatures 400 to 500 degrees Celsius lower than with compounds conventionally used in thick film technology, and in times which are an order of magnitude shorter than are required for sintering.

Suitable metals include copper, silver, gold, zinc, cadmium, palladium, iridium, ruthenium, osmium, rhodium, platinum, iron, cobalt, nickel, indium, tin, antimony, lead, bismuth and mixtures thereof. Examples of typical proportions of PARMOD™ mixtures containing an organic acid as the ROM and both metal flakes and colloidal metal powder are illustrated in Table 1 as follows:

**TABLE 1**                      **Acid-Based PARMOD™**

	Metal Flake	Metal Powder	Organic acid	Organic vehicle
Range	20-60%	10-45%	5-35%	0-35%
Preferred	40-60%	24-44%	5-20%	0-10%
Most preferred	40-60%	24-44%	10-20%	0-5%

Percents by total weight of the composition.

In a preferred embodiment, the metal mixture contains metal flake and colloidal or semi-colloidal metal powder where the total of flake plus powder is preferred to be 60-85% of the total mixture, and the powder is preferred to be 30-50% of the total metal. Larger amounts of organic vehicle may be added to reduce viscosity for certain applications.

The metal flakes have a major dimension between 2 to 10 micrometers, preferably about 5 micrometers, and a thickness of less than 1 micrometer. They can be produced by techniques well known in the art by milling the corresponding metal powder with a lubricant, which is frequently a fatty acid or fatty acid soap. The starting powders are usually produced by chemical precipitation to obtain the desired particle size and degree of purity. The flakes are sold for electronic applications as constituents of thick film inks and silver-loaded conductive epoxies.

The flakes perform several functions. They form a skeleton structure in the printed image which holds the other ingredients together and prevents loss of resolution when the mixture is heated to cure it. The flakes naturally assume a lamellar structure like a stone wall which provides electrical conductivity in the direction parallel to the surface of the substrate and provides a framework to lessen the amount of metal transport necessary to achieve the well-consolidated pure metal conductors which are the objective of this invention. They also provide low surface energy, flat surfaces to which the other constituents of the composition can bond.

The other metallic powder mixture constituent of the present invention are preferably colloidal or semi-colloidal powders with individual particle diameters below about 100 nanometers, preferably less than about 50 nanometers. The colloidal or semi-colloidal powder is preferably present in about 40% by weight of the total weight of the metal powder mixture. A primary function of these powders is to lower the temperature at which the compositions will consolidate to nearly solid pure metal conductors. The presence of fine metal powder has been found to be helpful in advancing this low temperature process with silver and essential to the consolidation of copper mixtures. It is important that they be present as individual particles. Metal



particles this small have a strong tendency to agglomerate into aggregates with an open skeletal structure.

Colloidal silver particles with a nominal diameter of 20 nanometers were shown to have an excellent state of dispersion and have been used in silver compositions and lowered the critical consolidation temperature from 300 to 260 degrees C.

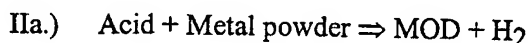
To achieve and preserve the desired degree of dispersion of colloidal metal it is essential to stabilize the particles so that they cannot aggregate. In the case of the silver particles they were stabilized by the presence of a surfactant which coated the surface of the particles and prevented metal-to-metal contact. Suitable surfactants include carboxylic acids and metal soaps of carboxylic acids. This favors chemical precipitation as a means of producing the powders, since they can be exposed to an environment which promotes stabilization from formation to final consolidation.

The Reactive Organic Medium (ROM) provides the environment in which the metal mixture is bonded together to form well-consolidated conductors. Many classes of organic compounds can function as the ROM. The common characteristic which they share and which renders them effective is that they have, or can form, a bond to the metal via a hetero-atom. The hetero-atoms can be oxygen, nitrogen, sulfur, phosphorous, arsenic, selenium or other nonmetallic elements, preferably oxygen, nitrogen or sulfur. This bond is weaker than the bonds holding the organic moiety together, and can be thermally broken to deposit the metal. In most cases the reaction is reversible, so that the acid or other organic residue can react with metal to reform the metallo-organic compound, as shown schematically below:

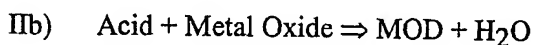


where R is a reactive organic compound and M is the metal.

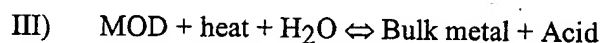
As an illustration of PARMOD™ mixtures containing MOD forming constituents such as organic acids, the reactions which take place in curing are as follows:



or



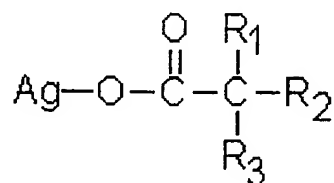
and



The effect is to consume the small particles and weld together the big ones to create macroscopic circuit conductors of pure metal. In place of acid, some other active organic reagent which will produce an easily decomposed metallo-organic compound from either the oxide or the metal could be used. An example would be the use of sulfur compounds to make mercaptides or nitrogen ligands to produce decomposable complexes.

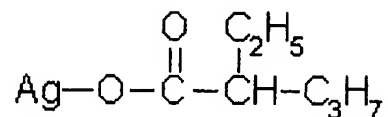
Examples of useful compounds are soaps of carboxylic acids, in which the hetero-atom is oxygen; amino compounds, in which the hetero-atom is nitrogen; and mercapto compounds, in which the hetero-atom is sulfur.

Specific examples of preferred ROM constituents are the carboxylic acids and the corresponding metallic soaps of neodecanoic acid and 2-ethyl hexanoic acid with silver and copper, such as. silver neodecanoate illustrated by the formula:

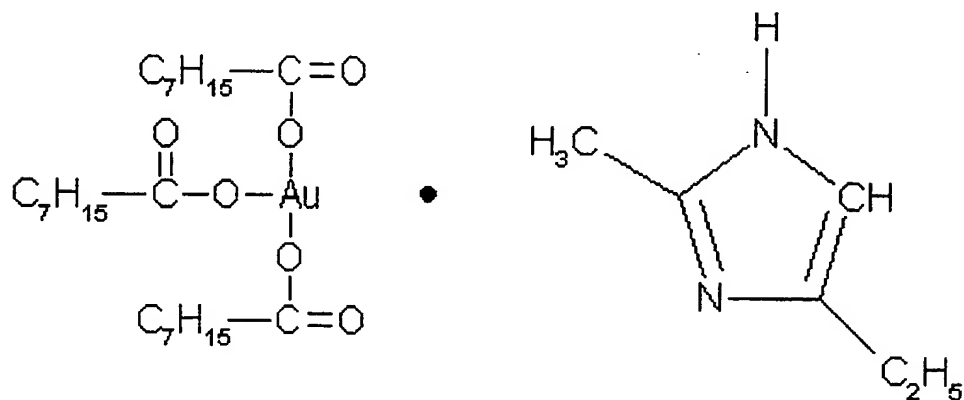


where  $R_1 + R_2 + R_3 = C_9H_{19}$

and silver 2-ethyl hexanoate as illustrated by the formula:

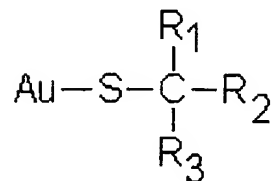


Gold amine 2-ethyl hexanoate is an example of a nitrogen compound.:



*Gold amine 2-ethyl hexanoate (gold amine octoate)*

Gold t-dodecyl mercaptide is an example of a sulfur compound:



where  $R_1 + R_2 + R_3 = C_{11}H_{23}$

These ROM compositions can be made by methods well known in the art. All of the above compounds are capable of decomposition to the respective metals at relatively low temperatures. For the silver neodecanoate and silver 2-ethyl hexanoate (silver octoate), the decomposition temperature is between 200 and 250°C. For the corresponding copper compounds, it is between 300 and 315 C. Gold sulfides decompose at very low temperatures in the neighborhood of 150°C. Gold amine octoate decomposes between 300 and 500°C. The copper and silver compounds can be reformed from the corresponding acids at the same temperature, so the reaction is reversible, as mentioned above.

In some cases it is convenient to add rheology-enhancing compounds well known in the art to improve the printing characteristics of the compositions of the invention. Alpha-terpineol has been used to reduce the viscosity of copper and silver compositions to facilitate screen printing. Alpha-terpineol also participates in the consolidation reaction by virtue of the acid character of the OH group bonded to an unsaturated ring. By selecting constituents and additives, it has proven possible to produce a range of printable compositions ranging from fluid inks with a viscosity of 15 centipoise to solid powders.

In a preferred embodiment, the following steps are used to utilize PARMOD™ compositions for metallizing high density microvias and interconnects:

- 1). An existing printed circuit or semiconductor device is coated with a photoimageable dielectric and then prebaked to drive off solvent and produce a dry film.
- 2) The desired pattern of microvias is photoimaged on the surface in alignment with the underlying pads or traces of the printed circuit or semiconductor device to which connections are to be made.
- 3). The image of the pattern is developed, for example, with a solvent or alkaline stripping agent, to remove the dielectric in the microvias.

4) PARMOD™ mixture is applied into the microvias. The PARMOD™ can just fill the microvias or it can be extended to connect some or all of them with printed circuit traces. by one of several methods. A preferred method for applying the PARMOD™ is simply to spread the PARMOD™ with a doctor blade to fill the microvias and leave the surface clean. The PARMOD™ material can also be applied by any acceptable printing method, for example, screening, stenciling, gravure printing, impression printing, offset printing, ink jet printing or electrostatic printing. The printed image may just fill the microvias or it can be extended to connect some or all of them with printed circuit traces. Electrostatic printing is a preferred method because a high resolution PARMOD™ image can be transferred to the uneven surface containing open microvias.

5). The circuit is heated in an appropriate atmosphere to a temperature required to cure the photoimageable dielectric. For polyimide materials this temperature is 350 °C for one hour. This is more than enough to cure any PARMOD™ composition including, specifically, copper For epoxy dielectrics, such as Probelec, the normal cure cycle is 150 °C for one hour. This would have to be increased to roughly 200 °C to cure silver PARMOD™, but the time could be shortened correspondingly to six minutes or less. At this point, the circuit has an added layer of dielectric with metallized microvias leading to the surface and, optionally, some printed circuit traces connecting them or connecting to pads defined by the printed image, as shown in Figure 1.

For interconnects which are finer than those which can be printed directly, another layer of photoimageable dielectric can be added, and a set of circuit traces can be imaged on it and developed, as above. While printed PARMOD™ traces can achieve approximately 5 mil (125 micrometer) lines and spaces, Photolithography can reduce this easily to 2 mils (50 micrometers) and very likely less.

The fine interconnects are metallized with PARMOD™ and cured as in 4) and 5) above to provide a plane of very high density circuitry, as illustrated in figure 2.

The process can then be repeated with layers of microvias, interconnects and circuitry, and so on, to build up a multi layered, high density structure of whatever complexity is needed to redistribute the I/O from increasingly large and fine pitch semiconductors, as illustrated in figure 3.

In another preferred embodiment, the PARMOD™ is not cured after each layer is filled. The PARMOD™ is applied and heat cured after a layer of microvias and a layer of interconnects have been formed in the dielectric. Thereby metallizing the structure, as shown in figure 2, in one operation; decreasing the number of curing steps required and the number of curing ovens required.

The advantages of using PARMOD™ in this application include: ease of applicability; the ability to make circuit connections simultaneously with metallizing microvias; the production of high quality, well-consolidated, well-bonded metal traces; the fact that the metallization process adds almost nothing in processing complexity and time to the application of the photodefined dielectrics themselves. This is in sharp contrast to the conventional catalyze, electroless plate, electroplate, etch, metallization process now used.

### Examples

The examples described below indicate how the individual constituents of the preferred compositions and the conditions for applying them function to provide the desired result. The examples will serve to further typify the nature of this invention, but should not be construed as a limitation in the scope thereof. which scope is defined solely in the appended claims.

#### Example 1

A silver PARMOD™ screen ink was prepared by mixing together 12.0 grams of Degussa silver flake, 3.0 grams of silver neodecanoate, and 1.35 grams of neodecanoic acid using a spatula. The resulting mixture was then milled for 30 minutes on a roll mill to give a homogeneous paste.

Damascene type silver metallization using the silver PARMOD<sup>TM</sup> ink was used to create a fan-out pattern of 100 micron lines with contacts to a copper surface. Ciba Specialty Chemicals' Probelec<sup>®</sup> epoxy-based photoimageable dielectric was used to create the image to be metallized. A Probelec<sup>®</sup> film was formed on the copper surface of a copper clad FR-4 board. The film was heat treated to remove solvents in accordance with the manufacturers instructions. The film was then photoimaged using a mask to create a line of vias on the copper surface and developed to remove the material from the imaged vias. The dielectric film covered the copper surface except in the imaged areas where the material was removed. Another film of Probelec<sup>®</sup> was formed on this imaged surface and processed as above to create a fan-out pattern of 100 micron lines leading from an array of 25 100 micron lines separated by 50 micron spaces to the previously imaged vias. The image was complete with the lower surface of the vias being the copper substrate and the lower surface of the lines leading from the vias being the first layer of Probelec<sup>®</sup>.

The PARMOD<sup>TM</sup> silver screen ink was then applied to the Probelec<sup>®</sup> imaged circuit. The ink was squeegeed across the surface of the circuit, filling in the conductive lines and vias with the ink. Excess ink on the surface was removed with wiping, and the circuit was thermally treated at 260°C for 255 seconds. The thermal treatment cured the silver ink giving pure silver and simultaneously cured the dielectric. Any remaining traces of silver on the surface were removed with abrasion using 1200 grit sandpaper. The resulting silver metallized image contained conductive, electrically isolated 100 micron lines with connections to the copper substrate through the vias which were separated by 50 microns of Probelec<sup>®</sup> dielectric at the point of closest approach.

### Example 2

A copper PARMOD<sup>TM</sup> ink was prepared by mixing 47 grams of copper flake, 29 grams of nanometer sized spherical copper powder mixed with neodecanoic acid (~77 wt% metal) and 15 grams of neodecanoic acid in a glove box. This premix was then further mixed on a 2-roll mill for 30 minutes in air. The gap setting on the mill

was 0.006" - 0.008". After milling, the ink was removed from the mill and stored in a plastic syringe from which it also was dispensed.

The copper PARMOD<sup>TM</sup> ink was applied to microvia holes (125 microns diameter, 5 microns deep) which had been created using DuPont Pyralin®, a photoimageable polyimide deposited onto a copper foil. The holes were filled with ink using a squeegee. No adhesive was used in the holes prior to filling with the copper PARMOD<sup>TM</sup> ink. The copper foil with the filled holes was heat treated at 360°C for 3 minutes in a N<sub>2</sub>-H<sub>2</sub>O-H<sub>2</sub> gas mix. The resulting filled holes were nearly completely filled with bright copper and the holes were conductive.

### Example 3

A copper PARMOD<sup>TM</sup> ink was prepared by mixing 30 grams of copper flake, 27 grams of 3 micron diameter spherical copper powder, and 25 grams nanometer sized spherical copper powder mixed with neodecanoic acid (~77 wt% metal) and 9 grams of neodecanoic acid in a glove box. This premix was then further mixed on a 2-roll mill for 30 minutes in air. The gap setting on the mill was 0.006" - 0.008". After milling, the ink was removed from the mill and stored in a plastic syringe from which it also was dispensed.

The copper PARMOD<sup>TM</sup> ink was applied to microvia holes (128 microns in diameter, 64 microns deep) which had been "drilled" into a double sided copper/Kapton laminate using a laser. The holes, which were filled with ink using a squeegee, were filled once and heat treated, then filled a second time and heat treated. The second pass more completely fills the microvia. No adhesive was used in the holes prior to filling with the copper PARMOD<sup>TM</sup> ink. The heat treating conditions for both passes was 245°C for 10 minutes in a N<sub>2</sub>-H<sub>2</sub>O-H<sub>2</sub> gas mix. The resulting filled holes were bright copper and conductive.

### Example 4

A copper PARMOD<sup>TM</sup> ink was prepared by mixing 49 grams of copper flake, 31 grams of nanometer sized spherical copper powder mixed with neodecanoic acid



(~77 wt% metal) and 11 grams of neodecanoic acid in a glove box. This premix was then further mixed on a 2-roll mill for 30 minutes in air. The gap setting on the mill was 0.006" - 0.008". After milling, the ink was removed from the mill and stored in a plastic syringe from which it is also dispensed.

The copper PARMOD<sup>TM</sup> ink was applied to a circuit fan pattern recited in example 1 which had been created using DuPont Pyralin<sup>®</sup> photoimageable polyimide deposited onto a copper foil. The fan pattern was filled with ink using a squeegee. No adhesive was used in the holes prior to filling with the copper PARMOD<sup>TM</sup> ink. The copper foil with the filled fan pattern was heat treated at 375°C for 90 seconds in a N<sub>2</sub>-H<sub>2</sub>O-H<sub>2</sub> gas mix. The resulting filled trenches were bright copper and conductive. The copper metal was firmly adherent to the polyimide as demonstrated by tape testing.

While the invention has been described with reference to preferred embodiments thereof, it will be appreciated by those of ordinary skill in the art that modifications can be made to the structure and form of the invention without departing from the spirit and scope thereof.

**What is Claimed**

**Claim 1.** A method for producing an electronic device having metallized holes and channels comprising the steps of:

- A). Applying a layer of a dielectric composition over a substrate, said substrate having a pattern of electrical conductors;
- B). Removing portions of said dielectric layer, said removed portions forming a pattern, said pattern being located in a position in alignment with said pattern of electrical conductors on said substrate;
- C). Filling said pattern in said dielectric layer with a composition, said composition being comprised of metal particles and a reactive organic medium, wherein said reactive organic medium is comprised of a decomposable compound or one or more reagents which form a decomposable compound with said metal particles; and,
- D). Curing the composition with heat and forming consolidated metal conductors in said pattern in said dielectric layer.

**Claim 2.** The method of claim 1 further comprising the steps of:

- E) Applying an additional layer of a dielectric composition over said consolidated metal conductors in said pattern in said dielectric layer on said substrate;
- F). Removing portions of said additional dielectric layer, said removed portions forming an additional pattern, said additional pattern being located in a position in alignment with said pattern of said consolidated metal conductors;
- G). Filling said pattern in said additional dielectric layer with said composition; and,
- H). Curing said composition with heat and forming an additional pattern of consolidated metal conductors in said additional dielectric layer.

**Claim 3.** The method of claim 2, wherein steps E) through H) are repeated one or more times, forming a multi-layered, electronic device.

Claim 4. The method of claim 1 wherein said easily decomposable compound in the reactive organic medium has a weak hetero atom bond to the metal such that it will decompose at a temperature which said substrate can withstand.

Claim 5. The method of Claim 2 wherein said hetero atom is selected from the group consisting of O, N, S, P, and As.

Claim 6. The method of Claim 1 in which said metal particles are selected from the group consisting of the group IB, IIB, IVA, VA, VI A, VII A and VIIIA metals, indium, tin, antimony, lead and bismuth.

Claim 7. The method of Claim 1 wherein said dielectric layer is comprised of photoimageable dielectrics selected from the group consisting of polyimides, acrylics, epoxies, and their combinations.

Claim 8. The method of claim 1 wherein said pattern in said layer of dielectric is comprised of microvias.

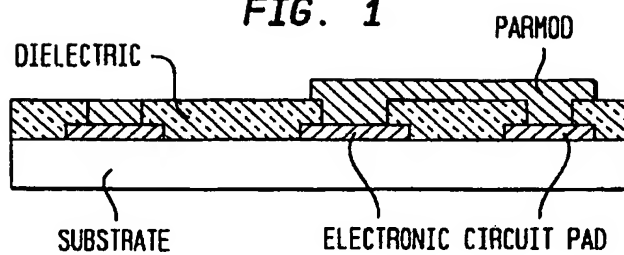
Claim 9. The method of claim 2 wherein said additional pattern is comprised of high resolution circuit traces.

Claim 10. The method of claim 1 wherein 2 wherein curing steps C) and D) are skipped and said composition of step G) simultaneously fills said patterns of steps B) and F) and is cured in step H).

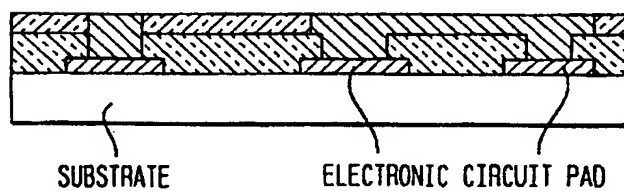
Claim 11. The method of claim 1 wherein steps A), B), C), and D), are repeated one or more times, forming additional metal filled patterned dielectric layers on top of existing one or more layers forming a multilayered structure.

Claim 12. The method of claim 1 wherein said pattern is filled using a method selected from the group consisting of screen printing, stenciling, gravure printing, impression printing, offset printing, ink jet printing, electrostatic printing, doctor blading, and squeegeeing.

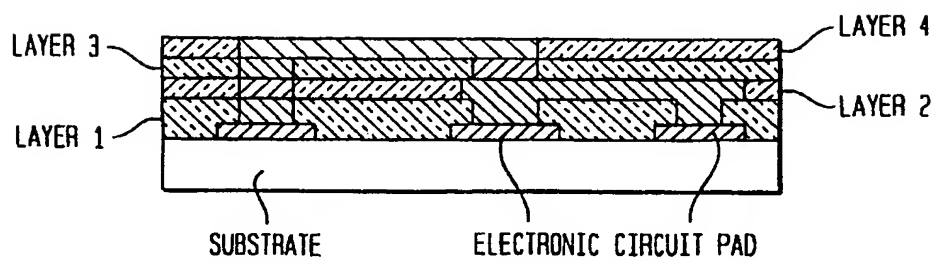
**FIG. 1**



**FIG. 2**



**FIG. 3**



# INTERNATIONAL SEARCH REPORT

Inter. application No.  
PCT/US98/20495

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H01L 21/445

US CL : 438/610

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,503,698A (GOLDBERG et al) 02 April 1996 (02.08.96) col. 2, lines 60-64; col. 3, lines 18-26; col. 4, lines 36-44.	1-12
X,P	US 5,728,626A (ALLMAN et al) 17 March 1998 (17.03.98) col. 3, lines 57-64; col. 4, lines 51-57; col. 5, lines 27-50; col. 7, lines 50-61; col.9, lines 18-24.	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

27 NOVEMBER 1998

Date of mailing of the international search report

31 DEC 1998

Name and mailing address of the ISA/US  
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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/20495

### B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

APS, JPOabs, DERWENT, WPI

search terms: organometallic(3w)paste, carboxylic(6w)paste, carboxylic and conductive, organometallic and conductive, particles(3w)conductive, (organometallic or carboxylic) and (conductor or conductive or conduct)